Accounting for Uncertainty in Future Climate Change and Evaluating Its Effects on Regional Air Quality

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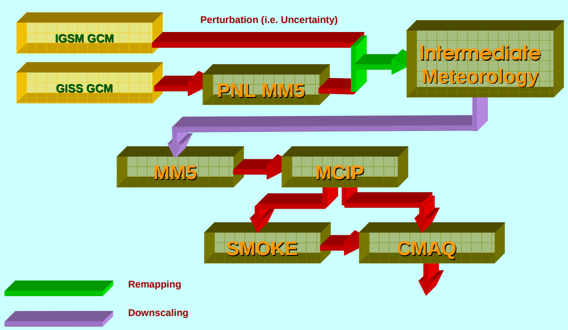
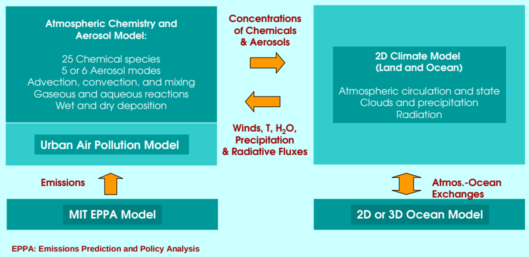
INTRODUCTION

Precise forecasting of future climatic conditions has typically been difficult due partly to the presence of large uncertainties in estimating various factors that can affect climate, e.g. emissions released into atmosphere from natural sources and human activities. This leads to an unclear level of uncertainty in evaluating future regional air quality which are dependent on both meteorology and emissions in the future. In this modeling study, a paradigm of regional air quality modeling over the continental US has been set up for control-year and future-year (~mid-century) cases. Emissions inventory from the US EPA Clear Air Interstate Rule (CAIR) (US EPA, 2005) is adopted and processed by the SMOKE program (CMAS, 2005). Two types of meteorological/climate data are used: a) From the NASA GISS global climate model (GCM) and b) From the MIT IGSM GCM (Prinn et al., 1998). The former dataset gives the base or nominal climate conditions driven by the IPCC's SRES A1B emissions scenario (IPCC, 2001) and was downscaled to a regional through the PSU/NCAR MM5 model (MM5, 2005) (Leung et al., 2005). The latter dataset is used to suggest uncertainty in future climate change, which is then incorporated into the modeling through the following two steps: 1) numerically mapping uncertainty in mean values of a meteorological set of interest (e.g. monthly mean temperature) onto the nominal future climate conditions and 2) meteorological downscaling to the regional scale using MM5.

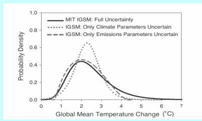
MODELING APPROACH



a) Modeling Setup



b) MIT IGSM Components



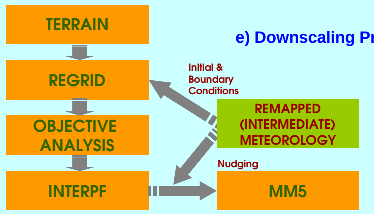
c) PDFs of Global Mean Surface Temperature Change (by IGSM) from 1990 to 2100

$$a(y,x,z,t) = \bar{a}(y,z,m) + a'(y,x,z,t)$$

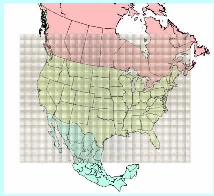
Expansion of 2D IGSM output into 3D:

1) Write a 3D time-dependent variable of interest ("a") using Reynolds decomposition (m = monthly mean specifically)
2) Using MM5 proxy data to derive (a') and (ā) for given months
3) Build index relations between them
4) Replace "ā" with IGSM output;
5) Reversely convert to "a" using new "ā" and "a'"
6) Replace "a" in MM5 proxy

d) Remapping Process



e) Downscaling Process

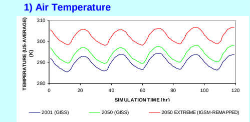


- 147 x 111 grids
- 9 vertical layers
- 36-km grid size
- Continental US + Parts of CAN and MX

f) CMAQ Modeling Domain

EXAMPLE MODELING RESULTS

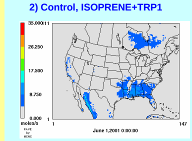
1) Air Temperature



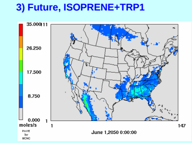
g) Comparison of 5-Summer-Day Simulation:

CONTROL/FUTURE/FUTURE (EXTREME)

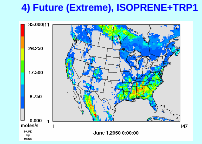
2) Control, ISOPRENE+TRP1



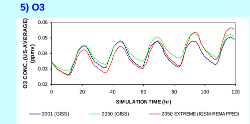
3) Future, ISOPRENE+TRP1



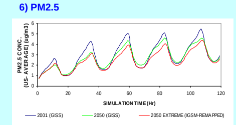
4) Future (Extreme), ISOPRENE+TRP1



5) O3



6) PM2.5



CURRENT & FUTURE WORK

- Enhance the remapping process
- Refine numerical procedures for the downscaling process through MM5
- Perform extended simulation: Multi-episodes
- Perform extensive statistical comparison among different future scenarios
- Use the Decoupled Direct Method (DDM) combined into CMAQ (Napelenok et al., 2005) to calculate the sensitivity of pollutant (both gaseous and particulate matter) concentration to emissions (in addition to concentration)

ACKNOWLEDGEMENTS

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